Four Wheel Drive Tractor Story

George R. Foster and John Sulik
Bryan and College Station, TX
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I (George) have been wood working for the last 20 years since my retirment as a soil erosion scientist with the USDA-Agricultural Research Service. I have designed and built model tractors, trucks, and construction and logging equipment**;** jewelry boxes; night stands; book cases; and head and foot boards The models progressed over time from crude toys for grandchildren to models with working parts without metal fasteners. My lastest model is the four wheel drive agricultural tractor described in this story.

Beginning of Story

The story of this particular tractor begins with my son-in-law, John Sulik, telling me that he is interested in taking up wood working. I wasn't surprised because he is good carpenter and has built several things. I gave him back issues of ***Woodsmith*** magazine, which has really good weekend projects.

In a couple of weeks, he surpised me by telling me that he is building his own CNC machine out of wood based on ***Woodsmith*** plans. I had seen the ***Woodsmith*** article on the CNC, but I didn't think that my wood working skills were sufficient to build the machine. After a few weeks, he had the machine built and running (See photos CNC 1-4 at the end of the narrative). He asks, "What can we build? " I immediately suggested a tractor since I love tractors and designing and making wooden tractor models. After building a couple of test tractors to make sure that we knew how to use the CNC machine, we jumped with great confidence into building the tractor described in this story.

I design the tractors that I build. In the past, I used the blacksmith approach in designing and building. I might do a rough sketch but mainly I visualized the parts and pieces, began cutting them out of wood, and assembled them. If a piece didn't work, a replacement is made, i.e., the cut and try method. Usually two prototypes were built before the final build of a particular model.

Using the CNC Machine

Several preliminary steps are required before the CNC machine is turned on to cut out wood pieces. The CNC machine is computer controlled that machines stock, in this case wood. The machine requires computer instructions to tell it what to do. In traditional wood working, lines would be marked on a piece of wood and the part would be cut out by sawing along the lines.

In using a CNC machine, a CAD computer program is used to draw lines on a computer screen, rather than on paper or on the wood. View 1 and View 2, figures at the end of the narrative, show drawings created with a CAD computer program during design. View 1 shows the side of the tractor that we built using the CNC machine. Other similar drawings were created for each individual part. The drawing for the front tractor body part is shown in View 2. After the lines are drawn (i.e., drawings like View 2 are produced), the CNC machine needs instructions that tells the machine what to do with the lines. A CAM computer program is used to give the CNC machine the instructions. These instructions include information on the thickness of the stock, the outline that is to be used to cut out the part, that a circle a hole drilled to a particular depth is to be drilled, that two parallel lines mean a groove cut to a particular depth, the type and size of the bit being used in the machining, and so on. In our case, I used the LibreCAD program to prepare the drawings like View 2 that John in turn used with the CAMBAM program to add the machining instructions.

This tractor had 35 pieces that were cut with the CNC machine and another 15 parts including spindles, hubs and wheels, that were produced on a lathe and other tradional wood working tools. The CNC machine produced pieces are shown in photo FWD 1.

Once the wood pieces are cut with the CNC machine, the next step is to assemble the pieces into the tractor. The tractor body is made of cherry; the grill, cab, and fuel tanks are made of mahogany; the hood is made of red oak; and the wheels are made of maple. The dowel rods are made of poplar and red oak. These woods were chosen because they machine well and the different woods give the tractor color contrast. The cherry, red oak, and mahogany wood pieces were cut from rough lumber purchased at a mill and lumber yard in Houston, Texas. The tractor uses pieces that are 3/6”, 1/4”, 3/8”, 1/2”, 5/8”, and 3/4” thick. Although the CNC machine could have been used to mill pieces to the required thickness, blanks were made by first resawing the rough lumber on a band saw and then planing blanks to the final thicknesses. Planing left a smoother surface than that left by the CNC machine. The planed wood requires less hand sanding than do pieces milled with the CNC machine. The 2-5/8” diameter wheels were turned from 2-7/8” diameter maple cyclinders purchased from Rockler. These blanks are used to make bats for chilldern playing baseball. Starting with a blank close to the size of the diameter of the wheels saved considerable work at the lathe. Furthermore, maple turns nicely and yields a very smooth surface.

To organize the CNC work, a spreadsheet was created where each piece was listed by thickness and the minimum width and length of the blank needed to cut out the piece. The CNC work proceded by starting with the thickest pieces and continuing to the thinnest pieces. Blanks were sized so that multiple pieces could be cut from the same blank. As each piece was cut, it

was placed in a clear plastic bag according to tractor subassembly (i.e., front body, rear body, hood and grill, front fenders, rear fenders, and cab).

The pieces cut with the CNC machine (shown in FWD 1) range in size from the front body that is roughly 4" wide by 7" long to the side grill that is about 1/2" wide by 3/4" long. The cab is made of pieces that have long slender elements that are 1/4" square.

Preliminary work is needed on the CNC cut pieces before assembly can begin. The CNC machine uses thin, small tabs to hold the work piece while it is being cut from the blank. These small tabs must be sanded away. Also, the edges of the pieces are sanded with 220 grit sandpaper to remove slight mill marks. Also, the surface of each piece are sanded with 220 grit sandpaper before assembly. The tractor is not easily sanded after final assembly because of small parts and irregular surfaces.

Axle Housings

The first step in assemblying the tractor is to make the axle housings (4 required) from 1" diameter oak dowel rod. Oak was chosen for its appearance, its strength, and its availability in a local home improvement store. These pieces are cut using a miter saw and a stop block to ensure that all four axle housings are exactly the same length. The miter saw ensured the required square cut. (See photo FWD 2). The next step was to drill 1/4" diameter ¾" deep bind holes in the axle housings to mount the spindles (axles) for the wheels. These holes are drilled using a lathe (See FWD 3) to ensure that the hole is centered in the axle housing and that the axis of the hole is coincident with the axle housing axis so that the wheels will be perpendicular to the tractor body.

The final step on the axle housings is to sand their ends on the lathe. A 1/16" deep, 1" diameter recess is milled into the tractor body to precisely locate the axle housings when they are glued onto the tractor body. The 1" diameter oak dowel is slightly larger than 1" while the 1" diameter recess cut by the CNC machine is slightly smaller than 1". Sanding the axle housing on the lathe maintained the roundness of the axle housings (See FWD 4).

The CNC machine drills a "1/4" diameter hole In the center of the recess that pases through the tractor body and into the sacrificial board on the CNC machine platform. The CNC machine is typically used to machine only one side of the stock. Turning the part over to machine the back side causes the CNC reference x-y coordinates to be lost. The 1/4" hole is used to reset the CNC reference point.

The axle housings are finished but are set aside.

Coupler Hitch

The coupler hitch at the rear of the front tractor body was not finished on the CNC machine because our CNC machine does not have a fourth axis. A drill press is used to drill a hole in the coupler hitch that connects the front and rear tractor subassemblies. This 17/64" diameter hole is slightly larger than the 1/4" diameter dowel rod that is used in the conncection, allows the tractor to articulate (bend) easily.

This hole must be precisely located. To achieve the required precision, the front tractor body is placed in an x-y vice on a drill press where the edge of the tractor body is placed flush with the stationary vice jaw. This placement ensures that the hole is drilled perpendicular to the main axis of the tractor body (see FWD 5). A radius must be precisely made on the hitch to ensure proper clearance with the coupler parts to be assembled later. A 3/4" diameter dowel is used to draw a 3/8" radius. A belt sander is used to sand the part to the radius line. The advantage of the belt sander is that the table provides a stable place to rest, hold, and rotate the tractor body rather than freehading the sanding. The 3/4" piece of scrap wood under the tractor body ensures that the tractor body is perpendicular to the sander belt.

Widening Panels

Widening panels are now attached to the front tractor body in several steps. Gluing these panels to the tractor body in the desired position is a challenge because the edges must be flush with the edges of the tractor body. When small parts are glued together, they are difficult to hold in place, especially if the clamps are at a slight angle. The glue acts as lubricant.

Two edges of the widening panels are cut o be precisely flush with the front tractor body, while the other two edges are cut with a 1/16" overhang that extends slightly beyond the tractor body. This overhang is removed in a later operation. The axle housing is used to locate the widening panel and help hold the panel in place during clamping. The axle housing is temporarily clamped to the body so that it can be removed after the widening panels are clamped (FWD 7) to prevent excess glue from attaching the axle housings to the panels.

Having the right amount of glue and having the glue evenly spread reduce sliding of the parts during clamping. It also reduces excess glue that must be cleaned. A glue brush works well to spread the glue (FWD 8). The widening panel is clamped to the front tractor body. The panel is rotated about the axle housing until the right edge of the panel is flush with the body edge at the back of the engine area (FWD 9). Once the panel is clamped, the axle housing housing is removed so that it won't become glued to the body by glue pressed out by the clamping (FWD 10).

Photo FWD 11 shows both widening panels glued to the front tractor body. Note that the top and front edges of the widening panels project slightly beyond the tractor body. A router and a flush cut bit (FWD 12) is used to trim the widening panels flush with the body (FWD 13). This proecedure works better than precisely cutting the panels with the CNC machine and then having to precisely glue them to the tractor body (FWD 14). Being able to use the router to make these flush cuts is why the axle housings were not attached in earlier steps.

Hood and Grill

Hood and grill pieces are attached next. The hood sides are attached first using a similar procedure to that used to attach the widening panels. In this case, a block is temporarily clamped to the cab area of the front tractor body to locate the hood sides as shown in FWD 15, again to minimze the problem of pieces shifting during clamping.

The next step is to attach the side grill panels. These pieces are small, about 3/4" on a side. The CNC machine is great for precisely cutting out these pieces and the opening in the hood sides where the side grill panels fit. Figures FWD 16 and 17 show the side grill pieces clamped. Once the glue has dried, the hood sides and grill side panels are trimmed with the flush cut bit (FWD 18).

Next, the hood top is clamped on as shown in FWD 19, again using a block clampedd at the end of the engine compartment to locate the top. Like other hood pieces, the hood top is cut oversized so that it can be trimmed to be flush with the hood sides.

Finally, the front grill pieces are attached as shown in FWD 20. Note that a jig is used to clamp the pieces because of the angled tractor front. Once the glue has dried, the front grill parts are trimmed with the flush cut bit on the router table.

Front Fenders

Next the front fenders and associated parts are attached to front tractor body. The deck for the operator's station is used to locate the fenders. The deck will be attached temporarily to the body at this time. However, prepartion work is needed on the CNC cut deck piece before it can be used. Figure FWD 21 shows the CNC cut piece.

The deck piece requires CNC machining on both sides, which presented a problem. Typicaly, the CNC only machines on one side of the stock. The problem with machining on both sides is that the reference points for the CNC x-y corodinates are lost when the piece is turned over, at least given our understanding at the time (remember, we are CNC beginners). Our solution was to add tabs to the ends the deck piece and use the CNC machine to drill holes through the stock into the sacrificial board below on the CNC platform. When maching is finished on one

side, the piece is turned over and located on the CNC platform using dowels in the CNC sacrificial board and the work piece. Consequently, the x-y reference position for the CNC was preserved.

A band saw having a fine tooth blade along and miter guage was used to cut off the deck tabs while leaving extra material. A belt sander was used to remove the extra material. See FWD 22 and 23. Using the miter guage on both the band saw and sander is critical for maintaining squareness of the deck piece.

The underneath groove in the middle of the deck is used to locate the deck on the tractor body so that it doesn't shift during clamping. The deck can be precisely located using this technique. The deck is clamped temporarily in place and used to locate the fenders and associated parts. Figure FWD 24 shows the deck clamped in place.

The fender assembly includes the fender itsself and a spacer (FWD 25) that holds the fender out from the body of the tractor. The spacer is required because of the thickness of the widening panels. A major advantage of the CNC machine is that it machined rabbets to fit around the deck. Also, the CNC machine was super on cutting the curved fenders.

FWD 26 shows the fender subassembly clamped in place. The fenders must be square underneath to the deck to ensure that the step piece will properly fit. (A confession: that wasn't done carefully enough when I attached the left fender. Consequently, sanding was required on the step piece.) Once the fender assembly is clamped, the temporarily clamped deck is removed (FWD 27) to avoid it being glued by excess glue pressed out by the clamping. The right side fender subassembly is attached by repeating the procedure used on the left side.

Next, the step piece is attached on the left side and a filler block is attached on the right side (FWD 2). These pieces must fit against the fender back. Sanding on the step piece was required because the left fender wasn't properly placed. Using the CNC greatly facilitated making the step block, which eliminated cutting and placing several small pieces. The deck is now attached permanently (FWD 29). (Another confession. The deck could have been attached before the left fender was attached.)

Cab

The front part of the tractor is now complete except for the cab and the axle housings. The next series of steps involve the back and front walls of the cab. The cab is not completely assembled at this time so that the finish can be more easily applied. Access with a brush to apply a finish is very limited inside the completed cab.

The cab can be assembled off the tractor and then attached to the tractor as a subassembly. However, assembly of the cab is very difficult using this approach. The following alternative approach along with a change in cab design produced a better cab that was more easily assembled.

Now that the deck is on the front tractor body, the operator's seat inside the cab isattached. A 1/16" deep recess was milled in the deck to locate the seat. The seat needs to be precisely placed. Without the recess, precisely locating and gluing the seat to the deck is difficult. Placement of the seat affects the fit of the cab walls. The seat is an essential structural member of the cab because of the support that it provides to the back wall of the cab. The recess in the deck has rounded corners. A chisel could have been used to square the corners, but instead, the corners of the seat were rounded. Photo FWD 30 shows the recess where the seat is placed, and FWD 31 shows the seat clamped and glued to the cab deck. Photo FWD 32 shows the back cab wall glued to the driver's seat and deck. The other cab walls are added later after the finish is applied.

However, we have one cab subassembly to make before moving to the rear of the tractor. The steering column is attached to the front cab wall. The steering column requires drilling a 3/16" diameter, 1/2" deep blind hole in the steering column to receive the steering wheel spindle. A 3/16" high collar is placed on the spindle to raise the steering wheel above the column. The steering column, spindle, and collar asssembly is shown in FWD 33. The steering wheel is cut from a 1" diameter poplar dowel rod as illustrated in FWD 34. The smaller 1/4" diameter dowel provides a handle to hold the 1" diameter dowel rod against the band saw fence and to slide it along the fence. .The steering wheel will be placed on the steering column after the finish is applied.

The steering wheel retainer and the retainers that hold the coupler and wheels are made from poplar dowel rods. Poplar wood is preferred for these pieces because poplar does split as easily as oak for example.

Assembly of the cab is completed cab after the finish is applied. Let's move to the rear of the tractor.

Rear Body

The rear body is placed in the x-y vice on the drill press to drill a 3/16" diameter hole for the implement hitch at the back of the tractor. A 1/4" diameter blind hole, 3/4" deep is drilled in the front of the rear tractor body (See FWD 35 and 36). A dowel rod placed in this hole is used to mount the coupler that connects the front and rear tractor subassemblies. The radius on the implement hitch radius is formed using the belt sander (See FWD 6). The radius is marked using a 3/4" diameter dowel.

Coupler

The next step is to drill holes in the U-shaped coupler that has 1/4” thick legs. The coupler was cut so that the outsidel legs of the U are parallel to the wood grain to provide for maximum strength in these legs. However, cutting the coupler out in one piece with the CNC machine resuts in the middle leg of the coupler being perpendicular to the grain and thus has little strength. To give this leg the required strength, a 3/16” thick piece of red oak is glued as a backing plate to the middle leg of the coupler.

The holes in the coupler must be carefully layed out and drilled. The holes much be perpendicuar to the repective legs of the coupler and the holes at the ends of the outside coupler legs must be pefectly aligned so that a dowel rod will pass easily through each outside leg. This alignment is achieved by drilling through both legs in the same pass of the drill bit. The x-y vice is invaluable in achieiving this precision (see FWD 37). After the holes are drilled in the outside legs, a 3/8” radius is formed on the ends of these legs. Care is taken to remove minimal material with the belt sander to maintain strength in this stressed area. After the radius is formed, the coupler is temporaily attached to the coupler hitch on the rear of the front tractor body to make sure that the coupler swings freely from side to side.

Rear Fenders/Tanks

Next, the tank pieces are glued together to make the rear fender/fuel tank subassembly. The fender/tank subassembly could have been milled out of a single blank, but the combined thickness exceeded the length of the end mill bit that we had available for the CNC machine. Thus, the CNC machine was used to cut out individual pieces that are glued together. Being able to precisely reproduce the curve on each piece was a welcome capability of the CNC machine. Also, we were impressed with the fender edge extension that the CNC machine cut.

Photo FWD 38 shows the individual fender/tank pieces with glue applied to one of the pieces. The glue should be applied carefully and evenly spread in a thin (but not too thin) coat. The glue has thickness that can cause the lines between the pieces to be more apparent. The pieces were clamped together using screw clamps as shown in FWD 39 to force out excess glue. However, the clamps are not a subsitute for thin glue. As shown in FWD39, a square and bench top are used to align the individual pieces. After the glue has dried, the belt sander is used to smooth the surfaces of each fender/tank subassembly. Photo FWD 40 shows a completed fender/tank subassembly after sanding. We think that the fender/tank subassembly with the fender extension is one of the neatest parts of the tractor. The CNC machine made construction of this part much easier than could have been accomplished with traditional wood working tools. When we make the next tractor, the deisgn will be revised to eliminate one of the individual tank pieces.

The next step was to attach the fender/tank subassemblies to the rear deck. First, we removed the tabs from the rear deck as we did for the front deck (see FWD 21). The rear deck has a groove on the bottom side to align the deck on the rear tractor body. The top side of the deck has two rabbets used align the fender/tank subassemblies for clamping. The tabs were used to perfom CNC machining on both sides of the deck.

Photo FWD 41 shows a fender/tank subassembly clamped to the rear deck. The blank from which the tank was cut is used as a jig to clamp the tank assembly to the deck. Without the jig, clamping the curved tank would have been very dificult.

The assembled fender/tank/deck is placed in the x-y vice to drill blind 1/4" diameter blind holes for the fuel tank caps (FWD 42). Next, the fender/tank/deck assembly is glued to the rear tractor body (see FWD 43).

Installing Dowel Rods

Dowel rods that represent the fuel tank caps and that hold the coupler that connects the front and rear tractor subassemblies are installed next. As shown in FWD 44, the end of the dowel rods that go into the blind holes are rounded so that the dowel rod be more easily inserted in holes. A scroll saw with a fine tooth blade and a zero clearance "insert" (FWD 45) is used to cut the dowel rods to length. The rods for both the fuel caps and coupler are cut longer than the final length. The longer pieces make installation of the dowel rods easier. After the dowel rods are glued in for the fuel caps, the rods are sanded to the desired height with the belt sander (see FWD 46). The dowel rod for the coupler is cut extra long so that the length can fitted to the coupler when it is attached to the body.

Glue is applied to a dowel rod when placing the rod in a blind hole. Otherwise the glue will prevent the dowel rod from going to the bottom of the blind hole. Sanding on the dowel rods is sometimes required because the dowel rod diameter may slightly exceed the hole diameter.

Installing Coupler

Installing the coupler may be the most difficult part of the tractor assembly. A retainer on the end of the dowel rod is used to hold the coupler in place. These same retainers are used to hold the wheels on the axle spindles. The retainers are made from a 1/2" diameter poplar dowel rod. A 2" length of dowel rod is cut and placed in the lathe that is used to drill a 1/4" diameter hole in the dowel rod (see FWD 3). A retainer 1/4" in length is cut with the scroll saw from the drilled dowel rod as shown in FWD 47. The left end of the drilled rod is sufficently long to hold the piece. A 1/4" diameter dowel rod is inserted in the right end of the drilled dowel rod. This inserted dowel rod is used as a handle to guide the piece through the saw and to hold the sawed off retainer piece so that it does not roll away.

Several trial fittings (see FWD 48) are made to install the coupler to the tractor rear body. The first trial fit is to temporaily attach the coupler to the front part of the tractor to ensure that the coupler can rotate freely from side to side. The parts should fit closely as possible to minimize the distance between the front and rear tractor subassemblies while maintaining sufficient material for strength.

A trial fitting is made to determine where to cut the dowel rod installed on the tractor rear body to the desired length. The length of this rod includes the height of the retainer and the thickness of the middle leg of the coupler and a slight clearance to allow the coupler to rotate. The end of the dowel rod should not intereferre with the coupler hitch on the front tractor body. If the dowel rod is too long, it can be shortened by sanding. The next trial fitting is with the retainer in place but not glued. Before this check is made, the end of the dowel rod should be sanded to ensure that the retainer has a slip fitting to the dowel rod so that the retainer can be put on and off the dowel rod with the fingers.

If the retainer is too high, it can be shortened by inserting a dowel rod in the retainer and using it as a handle to hold the retainer while the retainer is sanded on the belt sander. Once the coupler parts are deermined to be properly sized, the parts can be assembled and the retainer glued onto the dowel rod. Above, we noted that glue is applied to the dowel rod when the rod is inserted into a blind hole. In this case, the glue is put in the hole, i.e., the retainer. Otherwise, if the glue is placed on the dowel rod, the glue will be pushed into the coupler resulting in the coupler being glued to the dowel rod. To avoid this problem, the glue is placed in the retainer and the surface of the retainer adjacent to the coupler is wiped clean. The dowel rod is then pushed into the retainer, which pushes the excess glue out the other side of the retainer away from the coupler. The retainer is pushed on until it is flush with the end of the dowel rod while making sure that the coupler has sufficient clearance to rotate. The final assembly of the coupler to the tractor front body is made at the end of the tractor assembly.

Axle Housings and Spindles

Instalation of the axle housings and associated axles (spindles) is delayed until the major subassembies are completed. The housings and axles interfere with working on the front and rear subassemblies. Both the axle housings and axles are made from oak dowels rather than the poplar dowel used for the retainers. The oak dowels are about twice as strong as the poplar dowel in bending, which is a benefit in the high stress areas on the axles, especially given the long axles required for the wide dual wheels.

The blind holes in the axle housings are 3/4” deep. Since the 1/4” diameter oak dowels are slightly larger than the 1/4” diameter holes in the axle housings, the axles must be driven or pressed into the axle housings. However, the fit is so tight that the long slender axle dowel are

often broken. Instead, the axles dowel rods were placed in the lathe and sanded to reduce their diameter to a slip fit. The glue is place on the dowel rod, and the dowel rod isinserted in the axle housing. The excess glue is wiped away with a damp cloth.

Wheels

The last major part to be made for the tractor are the wheels. These wheels were made by turning them from maple blanks that are slightly larger in diameter than the wheels. The entire length of the blank is turned to the diameter of the wheels. A pair of calipers and a scale was used to measure the diameter of the blank as it is turned down (see FWD 49).

Once the blank is turned to the diameter of the wheels, the edges of the wheesl are marked on the blank, grooves are cut between each wheel, and a slight radius is put on the edges of each wheel (See FWD 50 and FWD 51). Once all of the wheels are formed on the blank, a miter saw is used to separate the wheels (See FWD 52). The sawed surface on each wheel is sanded smooth and flush using the belt sander (see FWD 53). Next, the holes in the wheels for the axle are bored using the lathe (FWD 54). A Fornstner bit and a drill presss are used to drill the recess in the wheels (FWD 55). Reducing the spindle speed on the drill press to about 800 rpm gave a better cut and eliminated burning the wood.

Applying a Finish

With completion of the wheels, the tractor subassemblies and individual pieces including the wheels and cab parts are ready to be coated with a finish. Three coats of an oil-based varnish are applied. The key is to apply the varnish in very thin coats and to sand between each coat with a 220 grit sandpaper. The final coat can be sanded with 320 grit sandpaper followed by an application of furniture polish. Better finishes than varnish can be applied, but I like the color that the oil-based varnish gives the wood. After each coat, the parts were hung to dry on a board with nails as shown in photo FWD 56 (The photo includes parts for two simple tractors being assembled at the same time.)

Final Assembly

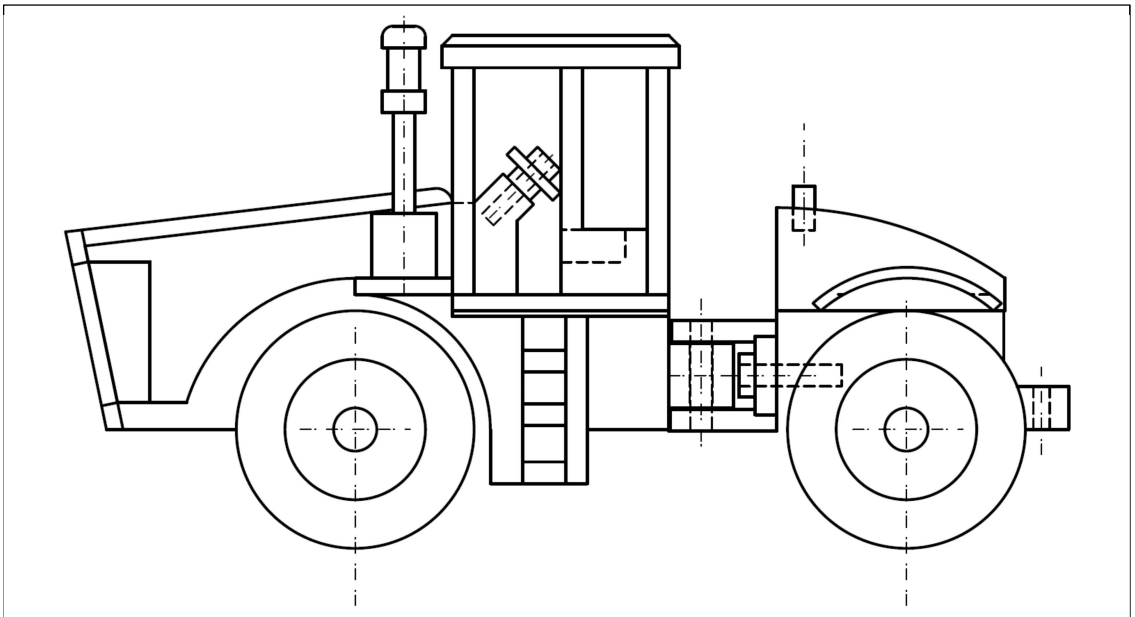
After the final varnish coat has dried, the final assembly of the tractor begins with the cab. First, the steering wheel and its retainer are installed on the steering column (FWD 57). The parts for the cab are shown in photo FWD 58. An important feature of this design are the grooves in the cab top where the ends of the cab side walls fit. The result is a much stronger cab and a cab that is easier to assemble. Before gluing, each mating surface must be sanded; otherwise the glue with not stick to the varnished surfaces.

The cab side walls are attached first (see FWD 59). The cab top is temporarily in place to ensure that the ends of the sidewalls are properly located. Photo FWD 60 shows the remaining cab parts assembled and clamped. The jigs at the front of the tractor are used to provide a good clamping surface because of the angle of the tractor front. With the cab attached, a shallow 1/4" hole is drilled in each side of the tractor near the cab where the air cleaner on the left side and the exhaust pipe on the right side will be attached (see FWD 61). The wheels are attached and now the front and rear tractor subassemblies are ready to be connected (See FWD 62).

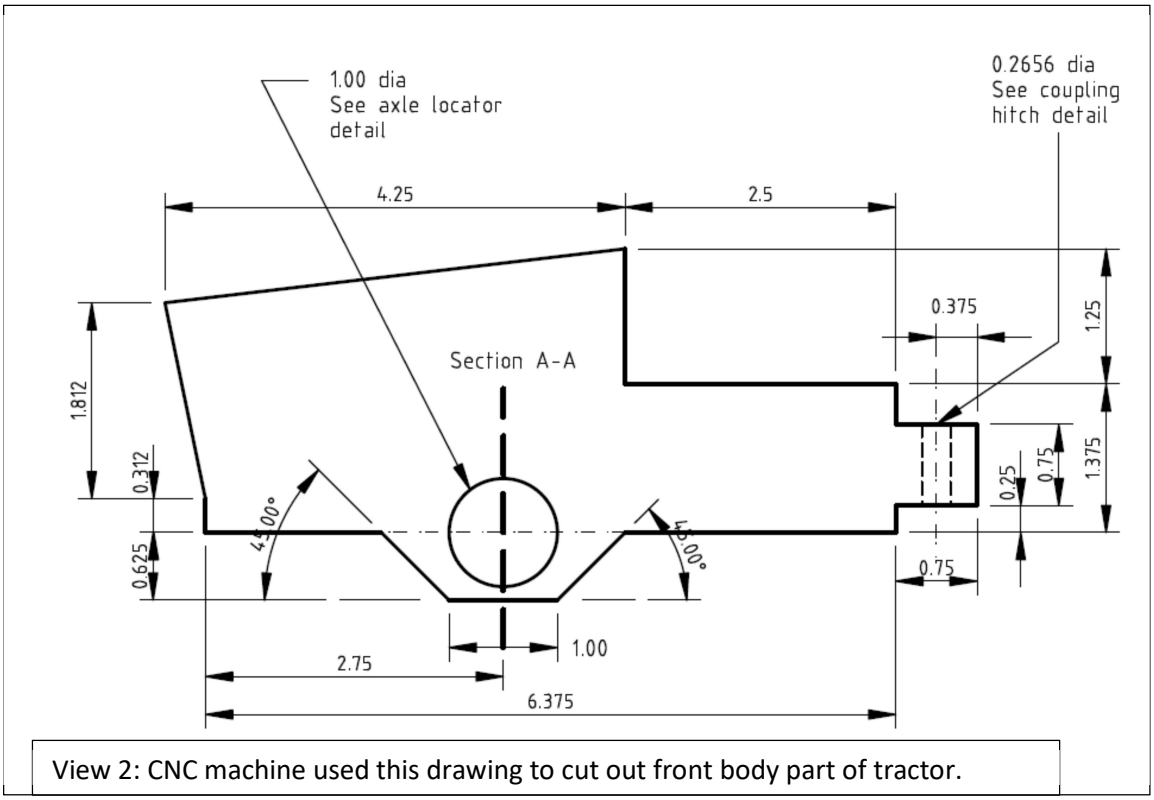
This step involves inserting a dowel rod through the outside coupler legs and the coupler hitch on the front tractor subassembly (see FWD 48). This step requires care. Sand the dowel rod for a slip fit. Make trial fits to obtain the dowel length so that the dowel ends are flush with the coupler legs. To glue the dowel in place, insert the dowel rod in the coupler the point that it begins to enter the second coupler leg. Apply glue to the top exposed end of the dowel rod and in bottom hole of the coupler. Push the dowel rod until it is flush with the coupler legs. Wipe away the excess glue. This procedure avoids getting excess glue into places where it should not be.

Completion

The tractor is now complete!!!!! (See FWD 63 and FWD 64). We are quite proud of the tractor and the work we did to build it. The ***Woodsmith*** CNC machine that John built performed well. We like the design and appearnace of the tracror.



View 1: Side view of tractor created during design.



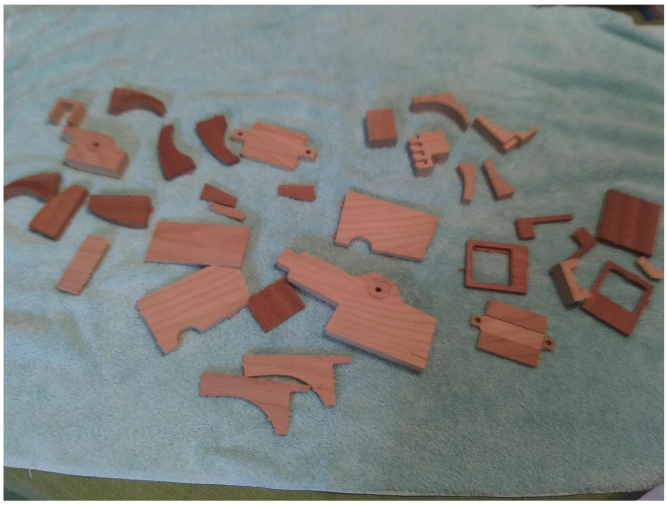
View 2: CNC machine used this drawing to cut out front body part of tractor.

CNC 1: platform and gantries of CNC machine built of wood.

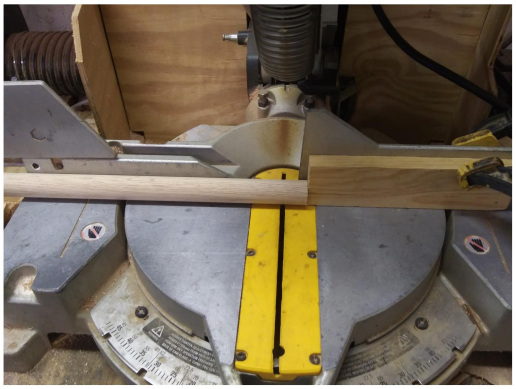
CNC 2: Side of CNC machine showing rails for gantries and steeper motors that move gantries under computer

CNC 3: Stepper motor that raises and lower router and end mill bit under computer control.

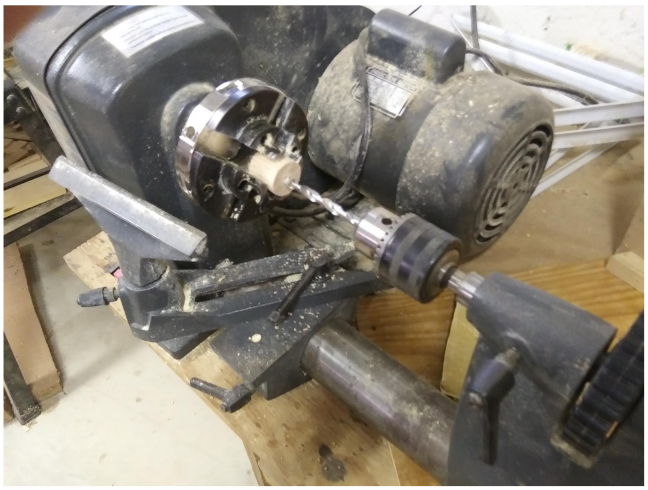
CNC 4: gantry, rail, stepper motors, power supplies, and controller in enclosure.

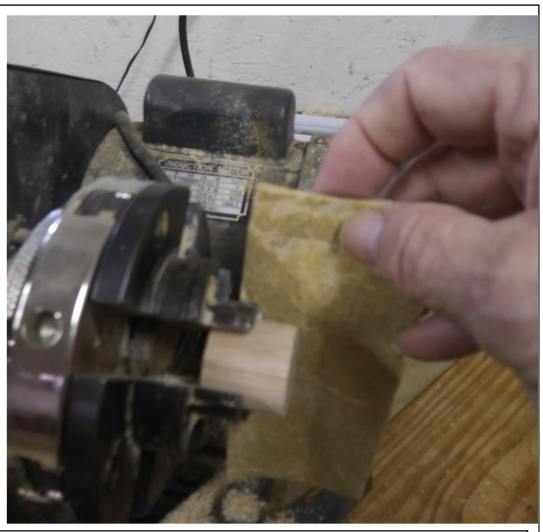


FWD 1: tractor pieces cut with CNC machine



FWD 2: miter saw used to cut axle housings.





FWD 4: Sanding end of axle housing.

FWD 5: Vice holding tractor body to drill hole for coupling hitch.

FWD 6: Sanding radius on coupling hitch,

FWD 7: clamping axle housing to body

FWD 8. Spreading glue on a widening panel

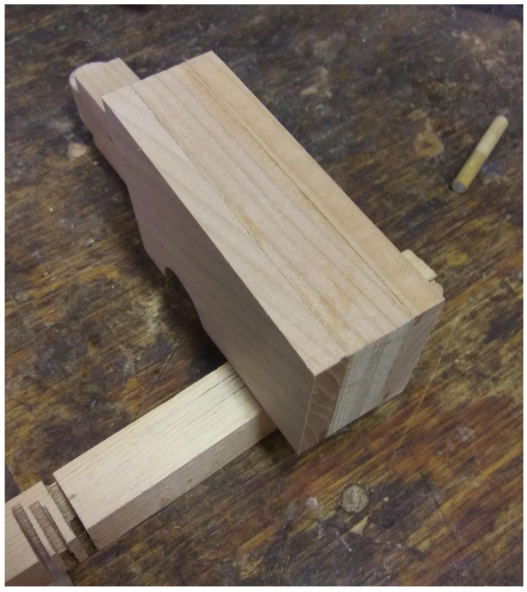
FWD 9: Widening panel clamped in
.

FWD 10: Axle housing removed after widening panels are clamped.

FWD 11: widening panels glued to front body. Note projected edges.

FWD 12: Flush cut bit and router table

FWD 13: trimming edges of widening panels.



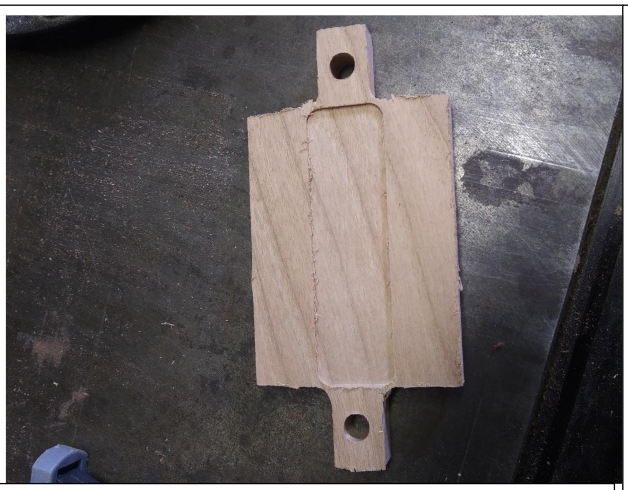
FWD 14. Widening panels trimmed flush with body top and front.

FWD 15: Clamping hood sides using a block clamped to tractor body to locate sides.

FWD 16: Side grill panel

FWD 19. Hood top clamped in place. Block at end of engine compartment used to locate top.

FWD 20: front grill pieces being clamped. Note jig on left used to clamped because of sloped tractor front



FWD 21: Deck piece as cut by CNC machine.

FWD 22: Using band saw with miter gauge to cut off deck tabs

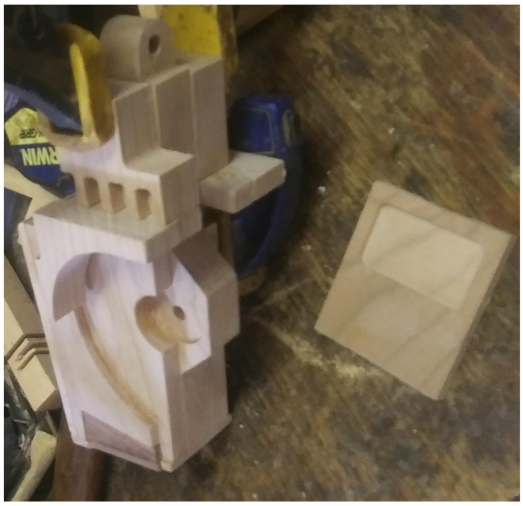
FWD 23 Belt sander with miter gauge used to sand deck to final dimensions

FWD 24 Front deck temporarily clamped in place to locate fenders.

FWD 25: Clamping fender spacer to fenders.

FWD 26: Fender assembly being clamped to tractor body using deck to locate fender, additionally, fender must be square to deck for the adjoining steps to fit.

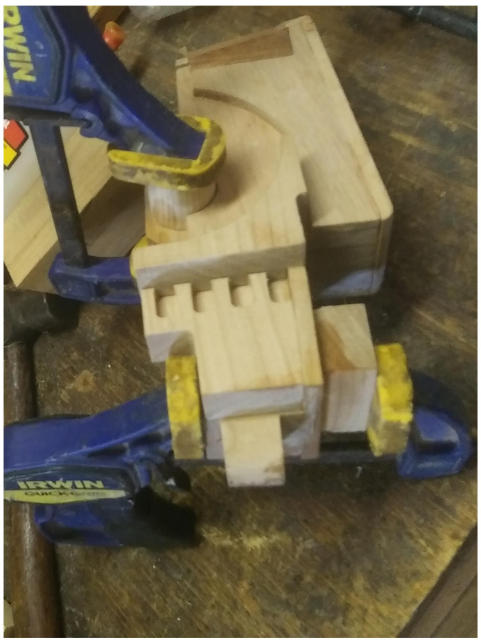
FWD 27. Fender assembly clamped in place and deck temporarily removed to avoid it being glued by excess glue.



FWD 28: step block on left side and spacer block on right side clamped.

FWD 29: Deck is attached.

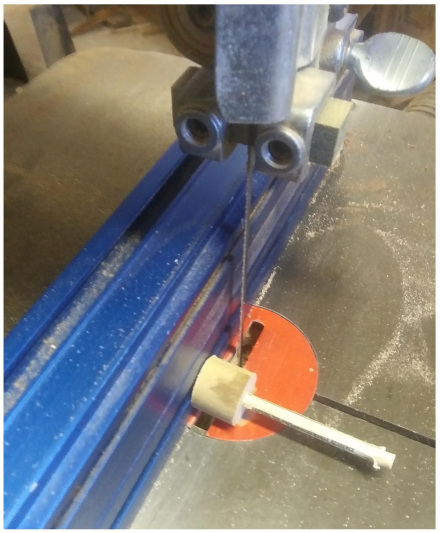
FWD 30: Ready to attach seat.



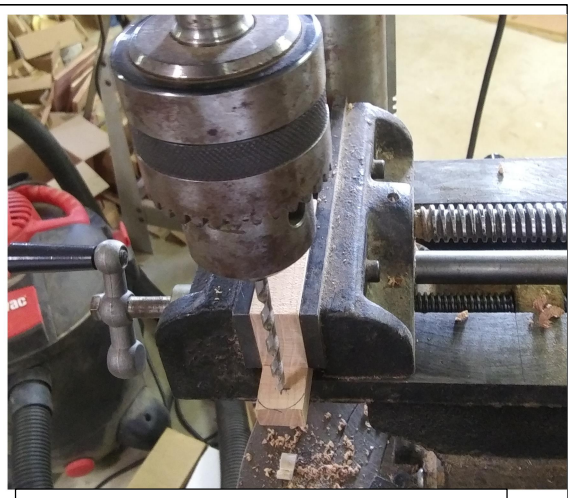
FWD 31. Seat being glued to cab deck

FWD 32: cab back wall being glued to seat

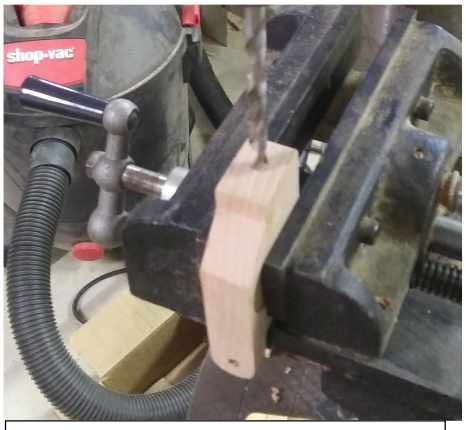
FWD 33: steering column, collar, and spindle



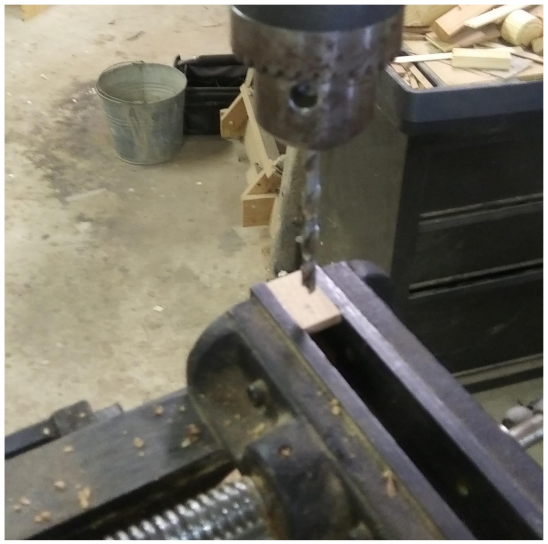
FWD 34: cutting steering wheel from 1” dowel blank



FWD 35: drilling hole in implement hitch

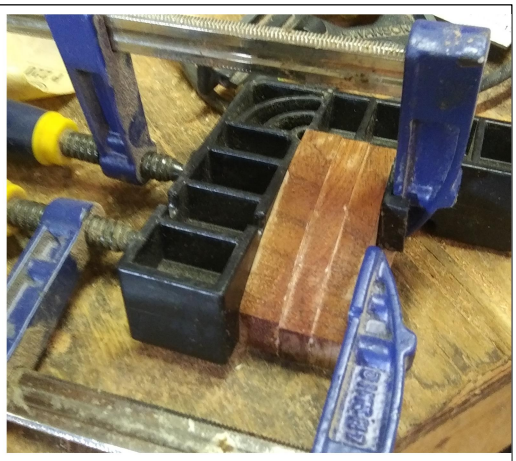


FWD 36: Drilling hold in front rear body where coupling will be attached.



FWD 37. Precise holes are required for the coupler.

FWD 38: Applying glue to fender/tank pieces



FWD 39: Using square and bench top to align fender/tank pieces for clamping.

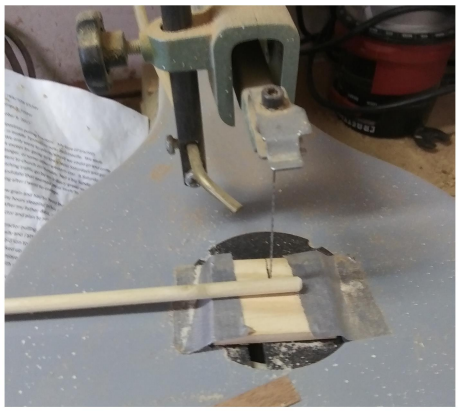
FWD 40: completed fender/tank assembly

FWD 41: using the cut out blank as a jig to clamp fender/tank assembly to rear deck.

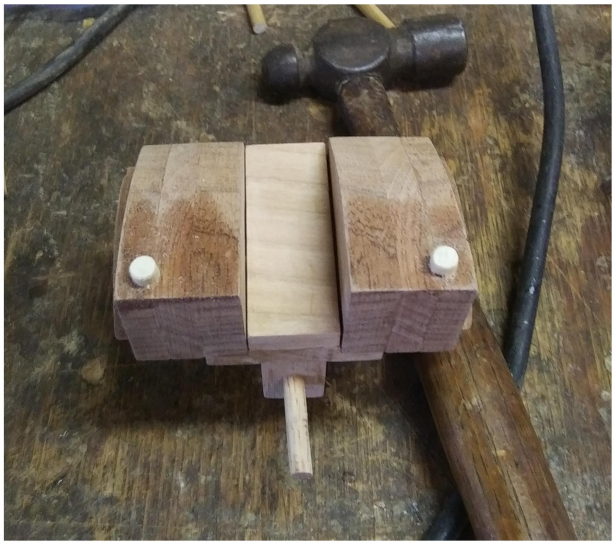
FWD 42. Fender/tank/deck assembly in the x-y vice so that blind holes can be drilled for the fuel tank caps.

FWD 43: Clamping the fender/tank/deck assembly to the tractor rear body.

FWD 44: rounding the end of a dowel rod



FWD 45: Cutting dowel rods to length with a scroll saw.

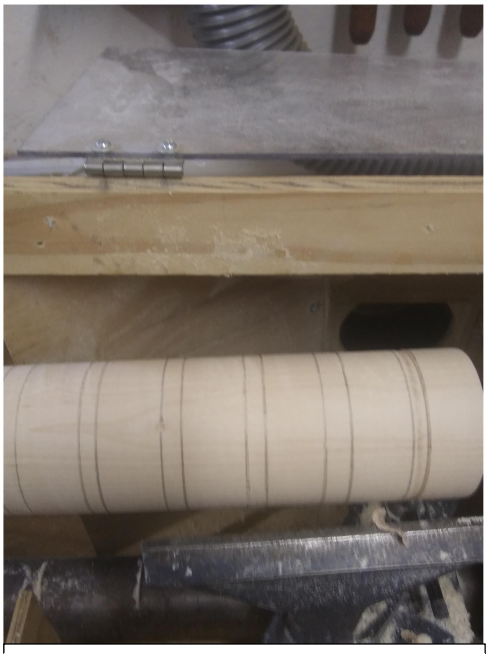


FWD 46: Installed dowel rods

FWD 47: Cutting off retainers with scroll saw.

FWD 48: trial fitting of coupler.

FWD 49: a pair calipers and a scale are used to measure the diameter of the turning.



FWD 50: edges of wheels are marked on blank.

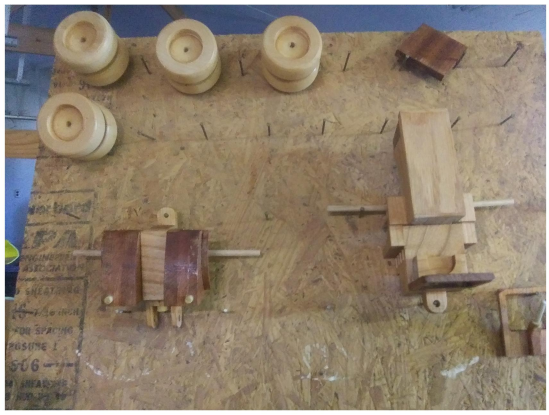
FWD 51. Grooves cut in blank at edge of each wheel. Slight radius put on edge of each wheel.

Fwd 52: Wheels separated using miter saw.

FWD 53: The sawed surface was sanded flush and smooth.

FWD 54: Axle holes in the wheels were bored using the lathe.

FWD 55. Recess in wheels was formed using a Forstner bit.



FWD 56: Just varnished tractor parts hung to dry.

FWD 57. Steering and retainer placed on steering column.

FWD 58: cab parts to be assembled.

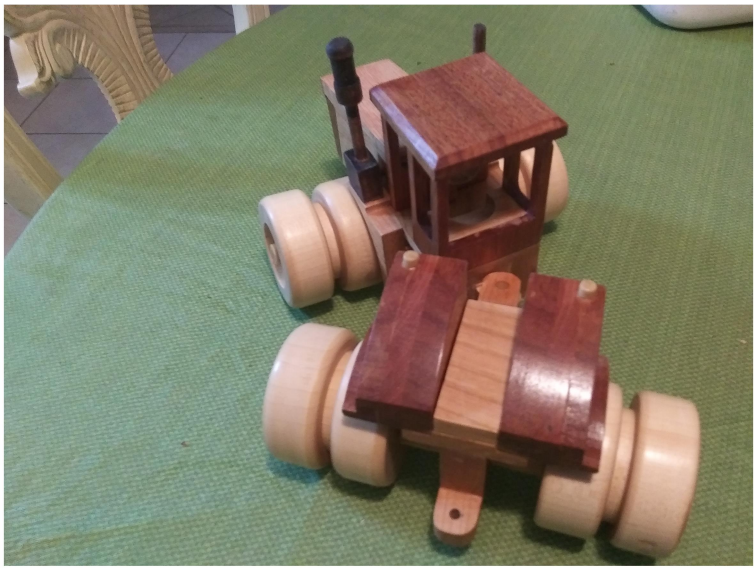
FWD 59: the cab sidewalls were attached first

FWD 60 remaining cab assembled and clamped

FWD 61: Holes drilled into hood on both sides so that air cleaner and exhaust pipe can be attached.

FWD 62: Wheels attached to tractor front and back.

FWD 63 Top view of completed tractor including air cleaner and exhaust pipe



FWD 64 Completed tractor!!!!!!!!